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ANNUAL REPORT

PLATINUM-GROUP METALS

By J. Roger Loebenstein

1990

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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U.S.
DEPARTMENT
OF THE
INTERIOR

Manuel Lujan, Jr.
Secretary

BUREAU
OF
MINES

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Director

September 1991

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COVER PHOTO
Platinum Canadian Maple Leaf coins shown in various sizes ranging from one-tenth troy ounce to 1 troy ounce. (Photo is courtesy of the Royal Canadian Mint.)

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PLATINUM-GROUP METALS

By J. Roger Loebenstein

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The platinum-group metals (PGM) are composed of six closely related metals: platinum, palladium, rhodium, ruthenium, iridium, and osmium. They commonly occur together in nature and are among the scarcest of the metallic elements. In terms of commercial importance, platinum and palladium are the two most important metals of the group. All of the metals are valued for their corrosion resistance and catalytic activity.

The Clean Air Act of 1990 was passed by the Congress and signed by the President. Provisions of the new law require a 35% reduction in hydrocarbons and a 60% cut in nitrogen oxides beginning in 1994. In addition, automotive catalytic converters must be guaranteed by manufacturers to last double the current 50,000 miles.

The price of rhodium soared to a record high of more than $7,000 per troy ounce briefly in June before settling down to the $4,000 to $5,000 range. The supply of rhodium is a problem of increasing concern to automotive manufacturers who use it to control nitrogen oxide emissions from cars and trucks. There are no substitutes for rhodium for this application.

DOMESTIC DATA COVERAGE

Domestic production data for PGM are developed by the U.S. Bureau of Mines from a voluntary survey of U.S. refiners. Of the 18 refiners to which a survey request was sent, 11 responded. These represent 85% of the total refined metal production shown in tables 5 and 6. Production for nonrespondents was estimated using prior-year levels adjusted for general industry trends.

BACKGROUND

Products for Trade and Industry

The basic forms of PGM are sponge or powder, which may be converted to other forms such as bars, pastes, or chemicals. The catalyst industry employs an extensive number of chemical compounds containing PGM. A typical PGM catalyst may consist of a platinum-rhodium gauze woven from wire. The electronics industry purchases PGM pastes, and the dental industry uses wire and a variety of alloys.

Geology-Resources

PGM deposits are associated with magmatic intrusions of mafic and ultramafic rocks. They also occur to a lesser extent as placer deposits. Layered deposits associated with stratiform complexes are the only ones mined principally for the PGM, with nickel, copper, and cobalt sometimes produced as byproducts. These are found in the Bushveld Complex, Republic of South Africa, and the Stillwater Complex, United States.

In other PGM deposits, such as those found in the Sudbury Complex, Canada, and Noril'sk, U.S.S.R., the PGM are produced as byproducts of nickel and copper mining.[1]

In the Republic of South Africa, it is interesting to note that base metals such as nickel and copper are important in generating revenues from the Merensky and Platreef ores. This is not the case at the Stillwater Mine in the United States, where platinum and palladium contribute about 100% of revenues.

Technology

Processing.—The processing of PGM ore entails four general steps: mining, concentrating, smelting, and refining. In the concentrating step, platinum ore is crushed and treated by froth flotation. The concentrates are dried, sometimes roasted, and then fused in a smelter furnace, producing a sulfide matte containing the PGM. The matte is treated in a refinery using solvent-extraction techniques to separate and purify the six PGM.

Recycling.—In North America, PGM are recovered by a small number of scrap refiners, as shown in table 1. Other companies collect scrap materials such as catalysts and PGM-bearing solutions and process them to increase the grade. These upgraded secondary materials are then sold to refiners. For example, Multi-Metco Inc., Anniston, AL, produces about a 90% concentrate of PGM from scrapped autocatalysts, which in turn is refined by another company. World Resources Co., McLean, VA, collects electroplating solutions, upgrades them, and sells the concentrate to another refiner. Most companies specialize in refining or upgrading a particular type of scrap, such as petroleum catalysts, autocatalysts, or electronic scrap.

Refiners often charge a fee or toll to "toll refine" scrap, ownership of the PGM content of the scrap remaining with the customer. For example, a refiner and/or fabricator would replace worn out catalyst with fresh catalyst and charge the customer for the refining and fabrication costs. In other cases, refiners purchase scrap, process it, and sell the refined metal. When scrap changes ownership in this way, it is referred to as nontoll scrap.

For statistical purposes, nontoll refined scrap is considered as old scrap and is added to supply, along with newly mined metal.

Because of their high value, PGM are routinely recovered from petroleum catalysts, chemical catalysts, automobile catalysts, glass fiber bushings, electronic

scrap, laboratory equipment, dental materials, and jewelry.

Major collectors and refiners of autocatalysts are shown in table 2. In the United States, only Multi-Metco refined any substantial quantities of autocatalyst PGM. Multi-Metco's output required further processing by other companies to produce commercial-grade metal. The other major refiners of scrapped automobile catalysts are in Canada, Belgium, and Japan.

Because used precious-metal scrap varies widely in value and grade, proper sampling and assaying is important to the industry. Fire assay techniques have long been used to determine the presence of precious metals. In addition to fire assays, PGM can be determined by chemical methods and instrumental methods such as X-ray fluorescence and spectrochemical methods.[2]

A list of independent PGM assayers is shown in table 3. The list is meant to be a sample rather than a complete list of assayers.

Economic Factors

Futures contracts are traded on the New York Mercantile Exchange (NYMEX) and the Tokyo Commodity Exchange for Industry (TOCOM), and to a lesser extent on the MidAmerica Exchange.[3] Futures contracts help producers and consumers of platinum and palladium lock in prices and allow speculators an opportunity to make profits. By comparing the current price with the price for future delivery, one can surmise whether market participants expect prices to rise or fall.

Platinum and palladium futures contracts, specifying 99.95% metal content, were traded on the NYMEX in units of 50 and 100 troy ounces, respectively. Table 4 shows the number of contracts traded on the last trading day of the year for 1987–90.

Trading of platinum futures contracts on the TOCOM began in 1984. The contract unit is 500 grams, the quality specifications are 99.9% purity, and prices are quoted in Japanese yen per gram.

In London, prices of physical platinum and palladium bullion are set each day in the morning and afternoon for the wholesale market. The eight companies participating in establishing prices are members of the London-Zurich Good Delivery Agreement, which sets standards for platinum and palladium trading in

TABLE 1

SELECTED NORTH AMERICAN PLATINUM-GROUP METALS REFINERS AND FABRICATORS

Company	Type	Plant location	Specialty
AT&T/Nassau Metals	Refiner	Gaston, SC	Electronics.
Do.	do.	Staten Island, NY	Do.
Degussa/Metz	Refiner, fabricator	South Plainfield, NJ	All.
Do.	Fabricator	Burlington, Ontario	Autocatalysts.
Du Pont Corp.	do.	Wilmington, DE	Electronics.
Engelhard Corp.	Refiner, fabricator	Carteret, NJ	All.
Do.	Fabricator	Seneca, SC	Catalysts.
Gemini Industries	Refiner	Santa Ana, CA	Do.
Handy & Harman	Refiner, fabricator	South Windsor, CT	Electronics.
Do.	do.	South Plainfield, NJ	Do.
Johnson Matthey Inc.	do.	West Deptford, NJ	All.
Martin Metals Inc.	Refiner	Los Angeles, CA	Electronics.
Multi-Metco Inc.	do.	Anniston, AL	Autocatalysts.
Noranda Ltd.	do.	Montreal, Quebec	Electronics.
PGP Industries Inc.	Refiner, fabricator	Santa Fe Springs, CA	Do.

TABLE 2

COLLECTORS AND REFINERS OF AUTOCATALYSTS

Company	Type	Plant location
A-1 Specialized Services & Supplies Inc.	Collector	South River, NJ.
Bowden Industries Inc.	do.	Covington, TN.
Brown Recycling & Manufacturing	do.	Somerville, AL.
Catalytic Converter Refining Co.	do.	Northlake, IL.
INCO Ltd.	Refiner	Sudbury, Canada.
Metallurgie Hoboken Overpelt/SGM	do.	Hoboken, Belgium.
Multi-Metco Inc.	do.	Anniston, AL.
Nissan Group/Ikeda	do.	Japan.
Parkans International Inc.	Collector	Houston, TX.
Sumitomo Metal Mining Co.	Refiner	Japan.
U.S. Scrap Co.	Collector	Los Angeles, CA.

TABLE 3

INDEPENDENT PLATINUM-GROUP METALS ASSAYERS

Company	Location
Accredited Laboratories Inc.	Carteret, NJ.
Alex Stewart (Assayers) Ltd.	Merryside, England.
Alfred H. Knight Laboratories Ltd.	Pompton Lakes, NJ.
Bondar-Clegg	Ottawa, Canada.
International Testing Laboratories	Newark, NJ.
Ledoux & Co.	Teaneck, NJ.
Umpire & Control Services Inc.	West Babylon, NY.

Europe. London and Zurich are the two most important European trading centers for platinum and palladium.

A time series of historical prices for each of the six PGM and a brief discussion of factors influencing prices are given in a U.S. Bureau of Mines publication entitled "Nonferrous Metal Prices in the United States Through 1988."[4]

ANNUAL REVIEW

Legislation and Government Programs

The Clean Air Act amendments of 1990 were passed, representing the fifth major effort by Congress to address clean air legislation. Provisions of this law deal with mobile sources and clean fuels, air toxics, acid rain, and ozone protection.

The amendments establish stricter standards for nonmethane hydrocarbons (NMHC), carbon monoxide (CO) and oxides of nitrogen (NO_x). Tier I standards for cars and light trucks call for 0.25 gram per mile (gpm) for NMHC, 3.4 gpm for CO, and 0.4 gpm for NO_x. These standards will be phased in between 1994 and 1998. Tier II standards are one-half of the Tier I standards and may go into effect between the years 2003 and 2006. In addition, catalytic converters must be guaranteed to operate for 100,000 miles, double the current limit.[5]

Strategic Considerations

Although production of platinum and palladium increased at the only PGM mine in the United States, the Stillwater Mine, the majority of PGM consumed in the United States was still derived from imported sources.

There were no changes in inventories of platinum, palladium, and iridium in the National Defense Stockpile in 1990. No purchases of rhodium or ruthenium were made, even though there is a stockpile goal for these two metals.

Production

The Stillwater Mine, southwest of Billings, MT, was operated by the Stillwater Mining Co. (SMC), owned 50% by Chevron Corp. and 50% by Manville Corp. Estimates from published sources showed that production of both platinum and palladium at the mine increased again in 1990. Small amounts of PGM

TABLE 4

NYMEX TRADING VOLUME FOR FUTURES CONTRACTS, DECEMBER 31

(Number of contracts)

	1987	1988	1989	1990
Platinum[1]	1,361,546	1,460,455	1,190,529	820,934
Palladium[2]	160,284	139,883	200,892	95,642

[1]50 troy ounces per contract.
[2]100 troy ounces per contract.

TABLE 5

SALIENT PLATINUM-GROUP METALS[1] STATISTICS

(Kilograms)

	1986	1987	1988	1989	1990
United States:					
Mine production:[2]					
Platinum	—	780	1,240	1,430	1,810
Palladium	—	2,330	3,730	4,850	5,930
Value[3] thousand dollars	—	r$23,606	r$35,601	r$45,764	$48,212
Refinery production:					
Primary refined	135	191	297	339	64
Secondary:					
Nontoll-refined	r11,015	r5,118	r4,788	r3,933	5,800
Toll-refined	35,924	44,935	46,403	46,253	46,447
Total refined metal	r47,074	50,243	51,488	r50,525	52,311
Stocks, yearend:					
Industry (refined)	40,187	38,412	r35,514	32,543	30,324
National Defense Stockpile:					
Platinum	14,079	14,079	14,079	14,079	14,079
Palladium	39,334	39,334	39,334	39,334	39,334
Iridium	920	920	920	920	920
Exports:					
Refined[4]	r11,880	13,423	20,301	23,082	20,148
Total	23,349	22,031	28,787	r38,301	55,044
Imports for consumption:					
Refined[4]	r115,925	r98,878	r110,947	111,107	120,631
Total	139,256	118,397	124,324	113,278	125,354
Imports, general	136,824	118,397	124,324	113,278	125,354
Consumption (reported sales to industry)	64,705	60,280	70,998	r78,483	77,487
Consumption, apparent[5]	r109,904	r95,458	103,302	r101,209	116,242
Net import reliance[6] as a percent of apparent consumption	90	91	91	90	88
Price, dealer, average, per ounce:					
Platinum	$461	$553	$523	$507	$455
Palladium	$116	$130	$123	$144	$114
World: Mine production[7]	r260,193	r273,581	r281,853	r283,158	e286,704

eEstimated. rRevised.
[1]The platinum group comprises six metals: platinum, palladium, iridium, osmium, rhodium, and ruthenium. Multiply by 32.1507 to convert from kilograms to troy ounces.
[2]Estimates for the Stillwater Mine are from published sources. A very small quantity of byproduct platinum and palladium produced from gold-copper ores was excluded.
[3]Value based on dealer prices.
[4]Excludes ores, scrap, and platinum grains and nuggets.
[5]1986 mine production excluded to avoid disclosing company proprietary data. 1987–90 includes mine production plus nontoll-refined production of secondary metal plus refined imports for consumption minus refined exports plus or minus changes in Government and industry stocks.
[6]Refined imports for consumption minus refined exports plus or minus changes in Government and industry stocks.
[7]1986 total excludes U.S. mine production in order to avoid disclosing company proprietary data.

TABLE 6

PLATINUM-GROUP METALS REFINED IN THE UNITED STATES

(Kilograms)

	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total[1]
PRIMARY METAL[2]							
Nontoll-refined:							
1986	19	116	—	—	—	—	135
1987	32	158	—	—	—	—	191
1988	46	248	2	—	(3)	—	297
1989	47	289	2	—	—	2	339
1990	2	62	—	—	—	—	64
SECONDARY METAL							
Nontoll-refined:							
1986	2,204	8,627	9	—	134	41	r11,015
1987	1,180	3,743	4	19	123	49	r5,118
1988	1,133	3,545	4	—	104	2	r4,788
1989	r1,134	r2,664	6	—	94	35	r3,933
1990	1,913	3,671	7	—	175	34	5,800
Toll-refined:							
1986	20,977	12,388	111	44	1,792	613	35,924
1987	22,580	19,169	102	25	1,895	1,164	44,935
1988	22,884	20,923	252	19	1,826	499	46,403
1989	24,058	20,037	219	1	1,565	373	46,253
1990	27,548	16,408	65	—	2,200	225	46,447
1989 TOTALS[1]							
Total primary	47	289	2	—	—	2	339
Total secondary	r25,192	r22,701	225	1	1,659	408	r50,186
Total refined metal	r25,239	r22,990	227	1	1,659	410	r50,525
1990 TOTALS[1]							
Total primary	2	62	—	—	—	—	64
Total secondary	29,461	20,079	72	—	2,375	259	52,247
Total refined metal	29,463	20,141	72	—	2,375	259	52,311

rRevised
[1]Data may not add to totals shown because of independent rounding.
[2]"Toll-refined" data were not reported for years 1986–90.
[3]Less than 1/2 unit.

were recovered by other companies as byproducts of domestic copper refining.

SMC opened a new smelter in Columbus, MT, to process PGM concentrates from the mine. PGM matte containing precious metals was airfreighted to Belgium for final refining and separation of the individual PGM. SMC had no plans to open its own PGM refinery or to have its concentrates refined domestically.

Sumitomo Corp. of America purchased Catalyst Collectors Corp. (CCC), Union, NJ, and CCC's network of autocatalyst collectors. Sumitomo, an international trading company, planned to offer scrap collectors financing capabilities, hedging capabilities, and precious-metal refining services.

Consumption and Uses

Reported sales of PGM by refiners is shown in table 7. For comparison purposes, the calculated apparent consumption for the individual PGM is also shown.

A summary of the typical uses for each PGM is shown in tables 8 and 9. Platinum, palladium, and rhodium were used in emission catalysts for light trucks (trucks weighing 14,000 pounds or less, gross weight) and automobiles. An informal survey of automobile catalyst manufacturers indicated that a typical emission catalyst in 1990 contained a total of about 2.7 grams PGM (approximately 2.18 grams platinum, 0.31 gram palladium, and 0.31 gram rhodium). These loadings were higher than in 1989, reflecting more stringent emission regulations.

There were variations in the quantities of PGM in each catalyst, depending on the vehicle's engine size, the normal operating temperature of the engine, and the manufacturer of the catalyst.

TABLE 7

PLATINUM-GROUP METALS[1] SOLD TO CONSUMING INDUSTRIES IN THE UNITED STATES

(Kilograms)

Year and industry	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total[2]
1986:							
Reported	30,513	27,681	382	21	2,906	3,203	64,705
Apparent consumption[3]	51,304	45,721	940	247	5,695	5,998	109,905
1987:							
Reported	25,471	30,956	250	29	2,692	882	60,280
Apparent consumption[3]	34,703	49,967	569	184	7,205	2,830	95,458
1988:							
Reported	31,125	34,241	495	23	3,292	1,821	70,998
Apparent consumption[3]	39,208	52,342	721	76	7,294	3,661	103,302
1989:							
Automotive[4]	18,774	4,886	—	—	1,982	—	25,643
Chemical	2,424	1,923	95	—	r177	26	r4,645
Dental and medical	632	8,424	105	57	1	15	9,233
Electrical	3,894	17,352	112	—	r177	r1,929	r23,464
Glass	1,130	181	—	—	177	1	1,489
Jewelry and decorative	418	179	7	—	205	6	814
Petroleum	2,859	2,543	—	—	27	—	5,429
Miscellaneous	3,566	3,786	81	—	273	61	7,766
Total[2]	33,698	39,273	400	57	r3,019	r2,037	r78,483
Apparent consumption[3]	47,035	45,299	604	30	6,112	2,129	101,209
1990:							
Automotive[4]	20,967	2,995	—	—	2,995	—	26,957
Chemical	2,080	2,369	22	—	169	16	4,654
Dental and medical	687	6,133	104	40	2	7	6,974
Electrical	3,907	17,997	111	—	274	1,406	23,698
Glass	431	346	1	—	31	1	810
Jewelry and decorative	431	177	11	—	195	8	818
Petroleum	3,274	1,488	—	—	—	—	4,762
Miscellaneous	4,280	3,612	199	1	520	202	8,814
Total[2]	36,055	35,116	448	40	4,187	1,641	77,487
Apparent consumption[3]	49,860	51,463	649	56	12,311	1,903	116,242

rRevised.
[1]Comprises primary and nontoll-refined secondary metals.
[2]Data may not add to totals shown because of independent rounding.
[3]Defined as mine production plus nontoll production of secondary metal plus imports minus exports plus beginning stocks minus ending stocks. Between 1986 and 1988, unspecified PGM imports and exports were divided evenly between platinum and palladium. Iridium and osmium exports included with ruthenium, in 1989 and 1990.
[4]1986–90 platinum, palladium, and rhodium sales to the automotive industry are estimated based on U.S. light truck sales and U.S. automobile production.

In electronic applications, ruthenium was the principal PGM used in thick film resistors, and palladium was the principal PGM used in thick film conductors, multilayer ceramic capacitors, and connectors. Platinum "targets" were used for sputtering thin films on circuit boards. Platinum-rhodium alloys were used for manufacturing thermocouples for precise temperature measurement.

For glass applications, most of the PGM, specifically platinum, rhodium, and palladium, were used in bushings for the extrusion of textile (continuous filament) glass fiber.

The nonautomotive catalyst applications of PGM were numerous. The petroleum refining industry used PGM, principally platinum, in reforming, cracking, and isomerization reactions. Chemical catalysts containing platinum and rhodium were used in inorganic syntheses of nitric acid and hydrogen cyanide. Palladium was used in the production of hydrogen

TABLE 8

TYPICAL USES OF PLATINUM, PALLADIUM, AND RHODIUM

Platinum	Palladium	Rhodium
Automobile catalyst	Automobile catalyst	Acetic acid catalyst.
Cancer drugs	Dental alloys	Automobile catalyst.
Coins	Hydrocracking catalyst	Glass bushings.
Cracking catalyst	Hydrogen peroxide catalyst	Nitric acid catalyst.
Crucibles	Multilayered capacitors	Thermocouples.
Fuel cell electrode	Thick films pastes	
Glass bushings	Vinyl acetate catalyst	
Hydrogen cyanide catalyst		
Isomerization catalyst		
Jewelry		
Nitric acid catalyst		
Reforming catalyst		
Targets for thin films		
Thermocouples		

TABLE 9

TYPICAL USES OF RUTHENIUM, IRIDIUM, AND OSMIUM

Ruthenium	Iridium	Osmium
Caustic soda electrode	Caustic soda electrode	Biological staining.
Chlorine electrode	Chlorine electrode	Pharmaceutical catalyst.
Resistor circuits	High-temperature crucibles	
	Reforming catalyst	

TABLE 10

REFINER, IMPORTER, AND DEALER STOCKS OF REFINED PLATINUM-GROUP METALS[1] IN THE UNITED STATES, DECEMBER 31

(Kilograms)

Year	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1986	20,426	16,958	611	12	1,475	705	40,187
1987	19,004	17,356	506	1	996	549	38,412
1988	18,438	14,837	432	8	1,165	634	r35,514
1989	14,791	15,182	522	36	1,096	916	32,543
1990	13,421	14,425	483	55	1,089	851	30,324

rRevised.
[1]Includes metal in depositories of the New York Mercantile Exchange (NYMEX); on Dec. 31, 1990, this comprised 4,272 kilograms of platinum and 2,034 kilograms of palladium.

peroxide. A wide variety of organic chemicals and pharmaceuticals were produced using PGM catalysts.

Stocks

In addition to the reported stocks held by refiners, importers, and dealers, end users of PGM held sizable quantities of PGM that were not reported to the U.S. Bureau of Mines.

Markets and Prices

The price of rhodium began increasing near the end of 1989, setting record highs along the way, until the price reached more than $7,000 per ounce briefly in June. During the remainder of the year, rhodium sold between $4,000 and $5,000 per ounce.

There were two primary reasons for the escalation in rhodium prices. The first had to do with production problems at an important South African refinery. The other reason for high prices was a lack of any substantial spot sales of rhodium from the U.S.S.R.

In October, the NYMEX introduced the trading of options on platinum futures contracts. In the past, the platinum futures market at NYMEX as well as other foreign futures markets have helped companies protect themselves from price volatility. Platinum options were designed to provide additional hedging and trading opportunities.

Foreign Trade

Imports of rhodium increased substantially, probably because of stockpiling by automobile companies, from 7 metric tons in 1989 to 13 metric tons in 1990.

World Review

Capacity.—Capacity for PGM production is generally cited in terms of platinum capacity. The data in table 14 represent rated capacity, defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

TABLE 11

AVERAGE PRODUCER AND DEALER PRICES[1] OF PLATINUM-GROUP METALS

(Dollars per troy ounce)

	Platinum		Palladium		Rhodium		Iridium		Ruthenium	Osmium
	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer	Dealer	Dealer
1986	519	461	131	116	1,196	1,157	600	414	73	704
1987	600	553	150	130	1,239	1,222	532	363	70	633
1988	600	523	150	123	1,275	1,218	420	306	61	592
1989:										
January	600	528	150	135	1,275	1,247	420	295	64	580
February	600	530	150	141	1,275	1,254	420	293	62	580
March	600	534	150	145	1,275	1,271	[2]	295	62	580
April	600	538	150	166	1,275	1,274	[2]	300	62	570
May	600	515	150	152	1,275	1,280	[2]	303	62	550
June	600	494	150	152	1,275	1,275	[2]	305	61	550
July	600	500	150	150	1,275	1,269	[2]	305	61	550
August	600	483	150	134	1,275	1,247	[2]	305	61	550
September	600	476	150	137	1,275	1,265	[2]	305	62	550
October	600	483	150	137	1,275	1,269	[2]	305	63	529
November	600	504	150	138	1,275	1,302	[2]	307	63	500
December	600	502	150	137	1,275	1,644	[2]	313	63	500
Average	600	507	150	144	1,275	1,300	NA	303	62	549
1990:										
January	600	492	150	134	1,275	2,031	[2]	315	63	505
February	600	516	150	135	1,275	2,098	[2]	310	61	444
March	600	494	150	130	1,275	2,058	[2]	310	61	425
April	600	475	150	127	1,275	2,108	[2]	310	61	421
May	600	484	150	118	1,275	2,308	[2]	305	61	400
June	600	479	150	115	1,275	2,960	[2]	305	61	400
July	600	475	150	116	1,275	5,040	[2]	305	61	400
August	600	486	150	115	1,275	5,014	[2]	305	61	400
September	600	319	150	103	1,275	5,271	[2]	305	61	400
October	600	415	150	94	1,275	4,720	[2]	305	59	400
November	600	416	150	93	1,275	4,405	[2]	304	60	400
December	600	414	150	87	1,275	4,769	[2]	309	61	400
Average	600	455	150	114	1,275	3,565	NA	307	61	416

NA Not available.
[1]Average prices calculated at the low end of the range and rounded to the nearest dollar.
[2]Producer prices discontinued Mar. 22, 1989.

Source: Metals Week.

The sudden and probably lasting rise in rhodium prices in 1990 has stirred speculation that despite rhodium's scarcity, it may become the chief revenue producer for South African mines, at least partly replacing platinum.[6] These conclusions are predicated on the assumption, shared by most experts, that rhodium will remain in short supply in the near term because of the lack of substitutes in automobile catalyst applications.

South Africa, Republic of.—Rustenburg Platinum Mines Ltd. announced its intent to develop a new PGM mine in Lebowa, to begin producing in 1994. The mine is part of the Platreef area, with in situ grades of 8.5 grams per metric ton of combined PGM and gold. The ore's platinum to palladium ratio is 1:1.

Lonrho PLC acquired the Karee Mine, owned by Impala Platinum Holding (Pty.) Ltd. (See table 14, footnote 4).

Johnson Matthey PLC announced plans to build a new autocatalyst plant in the Republic of South Africa with a capacity of 2 million units per year. The plant will cost $13.22 million and is to be in Germiston, near Johannesburg. Production is scheduled to begin next year and will supply primarily German auto manufacturers.

U.S.S.R.—General Motors Corp. (GMC) won a 5-year contract to supply

TABLE 12

U.S. EXPORTS OF PLATINUM-GROUP METALS, BY YEAR AND COUNTRY

(Kilograms)

Year and country	Platinum	Palladium	Rhodium	Iridium, osmium, ruthenium	Ores and concentrates	Waste and scrap	Total	
							Quantity	Value (thousands)
1989	8,414	13,005	1,156	507	173	15,046	r38,301	r$398,760
1990:								
Australia	102	63	—	31	—	—	196	1,640
Austria	14	57	—	—	—	—	71	341
Belgium	559	749	151	5	—	2,643	4,107	52,417
Brazil	12	22	8	—	—	—	42	297
Canada	728	824	326	14	300	290	2,482	31,307
China	—	1,303	—	1	—	—	1,304	5,434
France	1	63	—	1	—	71	136	656
Germany, Federal Republic of	800	644	1	84	59	3,052	4,640	54,269
Hong Kong	143	11	—	3	—	—	157	1,583
Italy	68	157	7	—	—	2,484	2,716	41,669
Japan	2,899	3,007	287	204	—	18,430	24,827	85,194
Korea, Republic of	495	141	106	9	—	3	754	19,792
Netherlands	2	1,496	—	—	—	—	1,498	6,919
Singapore	8	156	—	1	—	—	165	1,261
Sweden	10	31	—	175	—	191	407	1,586
Switzerland	196	309	35	—	22	—	562	6,450
Taiwan	631	356	—	16	27	—	1,030	10,666
U.S.S.R.	—	—	—	60	—	—	60	613
United Kingdom	733	1,127	46	54	—	7,322	9,282	90,119
Other	109	371	2	124	1	1	608	3,392
Total	7,510	10,887	969	782	409	34,487	55,044	415,605

rRevised.

Source: Bureau of the Census.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF PLATINUM-GROUP METALS, BY YEAR AND COUNTRY

(Kilograms)

Year and country	Platinum	Palladium	Rhodium	Ruthenium	Iridium	Osmium	Waste and scrap	Ores	Total	
									Quantity	Value (thousands)
1989	49,238	51,135	7,105	2,883	688	58	2,159	12	113,278	$1,381,693
1990:										
Belgium	1,465	5,329	164	—	—	—	9	—	6,967	53,837
Canada	98	1,035	25	8	2	—	652	76	1,896	16,396
France	437	6	307	—	—	—	—	—	750	10,737
Germany, Federal Republic of	3,457	745	331	37	25	11	95	—	4,701	100,074
Hong Kong	4	—	11	—	—	—	601	—	616	8,340
Italy	22	—	—	—	—	—	—	—	22	297

See note at end of table.

TABLE 13—Continued

U.S. IMPORTS FOR CONSUMPTION OF PLATINUM-GROUP METALS, BY YEAR AND COUNTRY

(Kilograms)

Year and country	Platinum	Palladium	Rhodium	Ruthenium	Iridium	Osmium	Waste and scrap	Ores	Total	
									Quantity	Value (thousands)
Japan	632	1,846	—	—	—	—	43	—	2,521	$25,557
Mexico	3	—	—	—	—	—	578	—	581	1,470
Netherlands	30	240	536	—	—	—	6	—	812	14,339
Norway	672	988	11	—	—	—	14	—	1,685	13,532
South Africa, Republic of	38,926	19,782	5,494	2,328	512	64	—	1	67,107	1,021,710
Switzerland	482	350	131	2	—	—	—	—	965	17,337
Taiwan	4	529	—	—	—	—	—	—	533	2,480
U.S.S.R.	455	12,023	3,073	15	—	—	—	—	15,566	335,697
United Kingdom	5,030	9,015	2,717	184	55	—	2,161	—	19,162	269,578
Other	560	104	298	12	9	—	455	32	1,470	14,449
Total	52,277	51,992	13,098	2,586	603	75	4,614	109	125,354	1,905,830

Source: Bureau of the Census.

TABLE 14

PLATINUM ANNUAL MINE CAPACITY OF MAJOR PRODUCING COMPANIES, AS OF DECEMBER 31, 1990

(Kilograms)

	Capacity
North America:	
INCO Ltd.	3,800
Falconbridge Ltd.	1,300
Stillwater Mining Co.[1]	1,810
Total	6,910
Africa:	
Rustenburg Platinum Mines Ltd.[2]	44,000
Impala Platinum Holdings (Pty.) Ltd.[3]	34,000
Western Platinum Ltd. (Lonrho)[4]	7,800
Barplats and Rand Mines[5]	1,000
Total	86,800
World total (rounded)	93,700

[1]Jointly owned by Chevron Corp. and Manville Corp.
[2]Owns Lebowa Platinum Ltd.
[3]Owns the Messina Mine.
[4]Owns the Karee Mine.
[5]Owns the Crocodile River Mine.

pollution-control and engine-control parts to Volga Auto Works, (VAZ), the U.S.S.R.'s largest automaker. GMC plans to begin shipping autocatalysts to VAZ's factory beginning in 1992.

The format of table 15 was changed in 1990 to show production of platinum, palladium, and other platinum-group metals.

Current Research

Scientists at AEA Industrial Technology Ltd. at Harwell, United Kingdom, investigated the use of tin oxide in combination with oxides of copper, aluminum, and chromium as a substitute for PGM in automobile catalysts.[7]

Rhodium is one of a number of products produced from the radioactive disintegration of plutonium. Scientists at IBC Advanced Technologies in Orem, UT, worked on separating rhodium from nuclear waste material. The separation process is based on a principle called molecular recognition. Chemical compounds called "hosts" are used to recognize the shapes of positively charged particles called "guests" and bind to them.[8]

OUTLOOK

Supply

Most of the major expansion programs for South African mines are still progressing, despite relatively low prices for platinum and palladium in 1990. High rhodium prices in 1990, averaging about $3,565 per ounce, partly compensated for lower revenue from platinum and palladium sales. A South African source showed the revenue (dollars per metric ton) of ore as shown in table 16.[9]

Rhodium plays an important role in providing revenue from the UG2 reef. In fact, almost one-half of the $66 in revenue is derived from rhodium, and approximately one-half is derived from platinum. Nickel, copper, gold, and the minor PGM provide limited revenue for South African deposits. In the United States, most of the $187 in revenue comes from platinum and palladium.

TABLE 15

PLATINUM-GROUP METALS: WORLD PRODUCTION, BY COUNTRY[1]

(Kilograms)

Country[2]	1986	1987	1988	1989	1990[e]
Australia, metal content, from domestic nickel ore:[e 3]					
Platinum	[4]115	130	105	100	100
Palladium	[4]428	490	410	400	400
Canada: Platinum-group metals from nickel ore:					
Platinum	5,242	4,700	5,393	4,244	4,829
Palladium	5,486	4,919	5,643	4,442	5,044
Other	1,462	1,311	1,505	1,184	1,336
Colombia: Placer platinum	447	638	810	964	950
Ethiopia: Placer platinum[3]	2	1	1	[r]2	2
Finland:					
Platinum	120	120	54	[r]60	60
Palladium	96	89	106	[r]100	100
Japan, metal recovered from nickel-copper ores:[6]					
Platinum	663	753	647	[r]1,031	1,358
Palladium	1,453	1,417	1,170	[r]821	1,061
South Africa, Republic of: Platinum-group metals from platinum ore:[e 7]					
Platinum	73,100	78,400	80,200	81,500	88,000
Palladium	32,300	33,900	34,400	35,800	38,900
Other	17,800	19,000	18,700	18,500	11,600
U.S.S.R.: Placer platinum and platinum-group metals recovered from nickel-copper ores:[e]					
Platinum	30,000	31,000	32,000	32,000	31,000
Palladium	81,000	83,000	85,000	85,000	84,000
Other	10,300	10,400	10,500	10,500	10,000
United States: Platinum-group metals from palladium ores:[e 8]					
Platinum	—	780	1,240	1,430	1,810
Palladium	—	2,330	3,730	4,850	5,930
Yugoslavia:					
Platinum	33	24	23	[r]22	29
Palladium	85	132	142	[r]140	135
Zimbabwe:					
Platinum	26	18	28	[r]25	20
Palladium	35	24	46	[r]43	40
Total	[r]260,193	[r]273,581	281,853	[r]283,158	286,704
Of which:					
Platinum	109,748	116,564	120,501	[r]121,378	128,158
Palladium	120,883	126,306	130,647	[r]131,596	135,610
Other	29,562	30,711	30,705	[r]30,184	22,936

[e]Estimated. [r]Revised.

[1]Table includes data available through Apr. 20, 1991. Platinum-group metal production by the Federal Republic of Germany, Norway, and the United Kingdom is not included in this table because the production is derived wholly from imported metallurgical products and to include it would result in double counting.

[2]In addition to the countries listed, China, Indonesia, Papua New Guinea, and the Philippines are believed to produce platinum-group metals, and several other countries may also do so, but output is not reported quantitatively, and there is no reliable basis for the formulation of estimates of output levels. However, a part of this output not specifically reported by country is presumably included in this table credited to Japan. (See footnote 6.)

[3]Partial figure; excludes platinum-group metals recovered in other countries from nickel ore of Australian origin; however, a part of this output may be credited to Japan. (See footnote 6.)

[4]Reported figure.

[5]Data are for years ending June 30 of that stated.

[6]Japanese figures do not refer to Japanese mine production, but rather represent Japanese smelter refinery recovery from ores originating in a number of countries; this output cannot be credited to the country of origin because of a lack of data. Countries producing and exporting such ores to Japan include (but are not necessarily limited to) Australia, Canada, Indonesia, Papua New Guinea, and the Philippines. Output from ores of Australian, Indonesian, Papua New Guinean, and Philippine origin are not duplicative, but output from Canadian material might duplicate a part of reported Canadian production.

[7]Includes osmiridium produced in gold mines.

[8]Estimates for the Stillwater Mine, from published sources. A very small quantity of byproduct platinum and palladium produced from gold-copper ores was excluded.

TABLE 16

REVENUE FROM PLATINUM-GROUP METALS DEPOSITS

(Dollars per metric ton)

UG2, Republic of South Africa	66
Merensky, Republic of South Africa	78
Platreef, Republic of South Africa	93
Great Dyke, Zimbabwe	57
Stillwater, United States	187

Demand

Future demand for PGM should continue to grow worldwide given the strong demand for a cleaner environment. Catalytic converters for controlling automobile emissions are currently used in Australia, Canada, Japan, Republic of Korea, Taiwan, United States, and many Western European nations. Brazil, Hong Kong, and Mexico are expected to start using catalytic converters in the very near future. The potential market for the catalytic converter is huge given the fact that there are 500 million motor vehicles worldwide.

In the United States, California has for years had the most stringent automobile emission regulations, setting the tone for Federal standards. The California Air Resources Board is seeking to introduce zero emissions for 2% of vehicles by the year 2000. Other States, such as New York and Massachusetts, are opting for California standards instead of the more lenient Federal standards.

In addition to controlling emissions from motor vehicles, the Clean Air Act of 1990 controls emissions of air toxics and chlorofluorocarbons. More than 189 air toxics emitted from bakeries, dry cleaning operations, chemical plants, paint plants, paper plants, and other industrial sources are regulated. Catalysts containing PGM are expected to play some part in controlling air toxic emissions.

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